



Cr-FREE METALLIC-CERAMIC COATINGS

ASETS Defense 2014

**Fort Myer, VA,
November 18-20, 2014**

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Coatings for Industry**

**319 Township Line Road
Souderton, PA 18756**

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Aluminum-Ceramic Coatings on Gas Turbine Compressors

❑ Essential to Life of Steel Parts

- cases, blades, vanes, shafts

❑ Various Coatings and Systems

- Alseal 518 & 519
- SermeTel W & 962
- IP9183 & 9442
- Ceral 114 & 34
- SermeTel 5380DP



Aluminum-Ceramic Coatings

- ❑ **Slurries of Al in chromic & phosphoric acids**
- ❑ **Spray and Bake.**
 - **Chemically bonds to steel.**
- ❑ **Very Durable**
 - **Stable to more than 1000F (540C).**
 - **Resists salt corrosion, even when heated.**
 - **Unaffected by water, fuel, oils.**
 - **Tightly Adherent. Resists chipping.**

Aluminum-Ceramic Coatings

❑ Introduced in 1960's

❑ Technology Evolved

- Polished (blades & vanes) – 1975
- Corrosion Resistant Sealer – 1978
- Low Temp. Cure – 1980
- Polished & Sealed – 1980
- Dense & Smooth - 1987

❑ Now Widely Specified . . .

- PWA, CPW, GEAE, GE Energy, Siemens, others
 - Materials - PWA 595, GE A50TF1, CPW 88 and more
 - Processes – PWA 110, GE F50TF62, and more

❑ . . . And Used

- JT3D, JT8D, CF6-, T700, Allison 250, PT6-, etc.

Al-Chromate/Phosphate Slurries Contain Hexavalent Chromium

PEL = 5 micrograms/m³

No Cr⁺⁶ Remains After Cure

Source of Cr⁺⁶ in Depots

PEWG

Ultimate Green Engine

(circa 2006)

- ☐ **Effort to Remove Cr⁺⁶ from Repair Depots**
- ☐ **PEWG AFRL-ML-WP-TR-2007-4069**
Compared . . .
 - **Aluminum-Inorganic Silicate**
Coatings For Industry (CFI)
 - **Al-Chromate/Phosphate (Std.)**
Sermatech (now Praxair/PST)

Aluminum-Silicate Comparable to Aluminum-Chromate/Phosphate

- ❑ Humidity Resistance
- ❑ Galvanic Corrosion Resistance
 - >3000 hrs., scribed & unscribed, ASTM B117 salt fog.

**no rust, pitting, or
undercutting at scribe**

(Al-silicate on 1010 carbon steel,
<10 ohms resistance as burnished)



Source: AFRL-ML-WP-TR-2007-4069, Sept. 2006

Aluminum-Silicate Comparable to Aluminum-Chromate/Phosphate

- ☐ Humidity Resistance, Galvanic Corrosion Resistance
- ☐ Heat/Salt Resistance
 - Ten test cycles
 - One cycle = 6 hrs. @ 875F / 16 hrs. salt fog

1010 carbon
steel

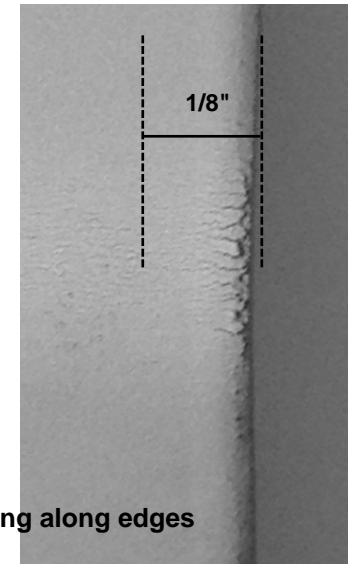
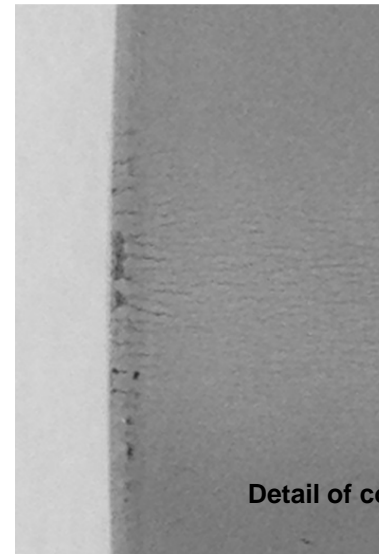
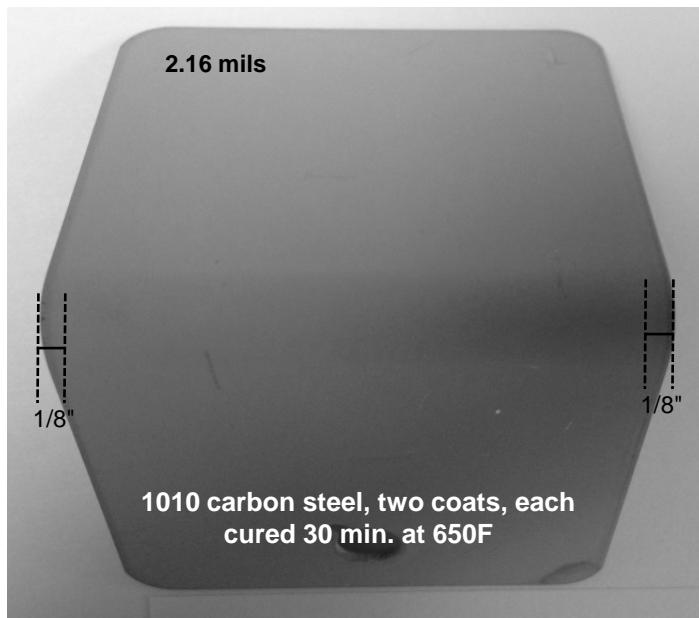
<10 ohms
resistance as
burnished



Source: AFRL-ML-WP-TR-2007-4069, Sept. 2006

Aluminum-Silicate Comparable to Aluminum-Chromate/Phosphate

- ☐ Humidity, Galvanic Corrosion, Heat/Salt Resistance
- ☐ Adhesion & Compatibility
 - 90 degree bend around 8X dia. mandrel



Aluminum-Silicate Comparable to Aluminum-Chromate/Phosphate

- ☐ **Humidity Resistance**
- ☐ **Galvanic Corrosion Resistance**
- ☐ **Heat/Salt resistance**
- ☐ **Adhesion/Substrate Compatibility**

Source: AFRL-ML-WP-TR-2007-4069, Sept. 2006

Sealed Aluminum-Silicate Not Comparable to Sealed Aluminum-Chromate/Phosphate in PEWG Evaluation

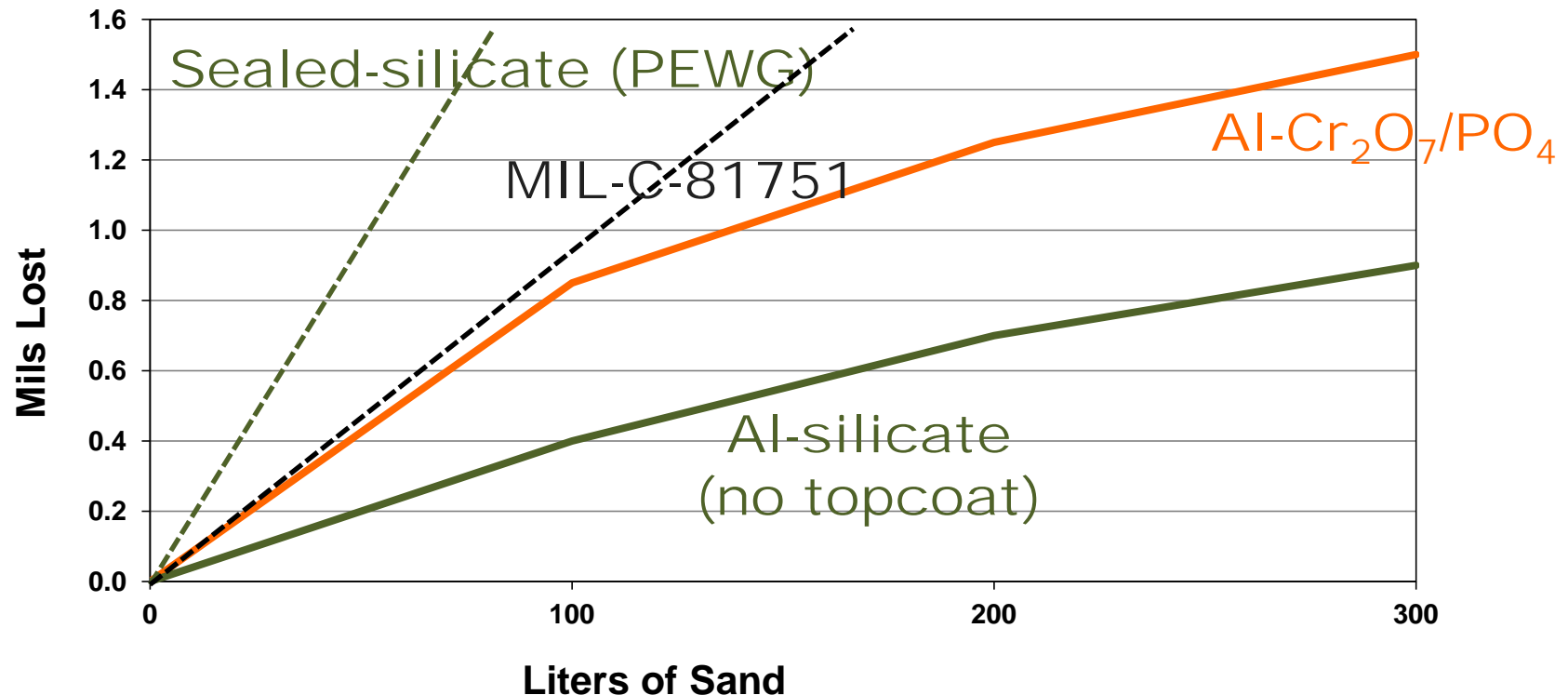
- ☐ Corrosion Resistance – No Post Treat**
- ☐ Abrasion Resistance**
- ☐ Hot Oil, Water Resistance - Sealer**

Source: AFRL-ML-WP-TR-2007-4069, Sept. 2006



Abrasion Resistance of Aluminum-Silicate Without Sealer Comparable to Al-Chromate/Phosphate

- **Falling Sand Test of Al-Silicate Basecoat**
> 100 L sand per 1 mil (25 μm) per ASTM D968

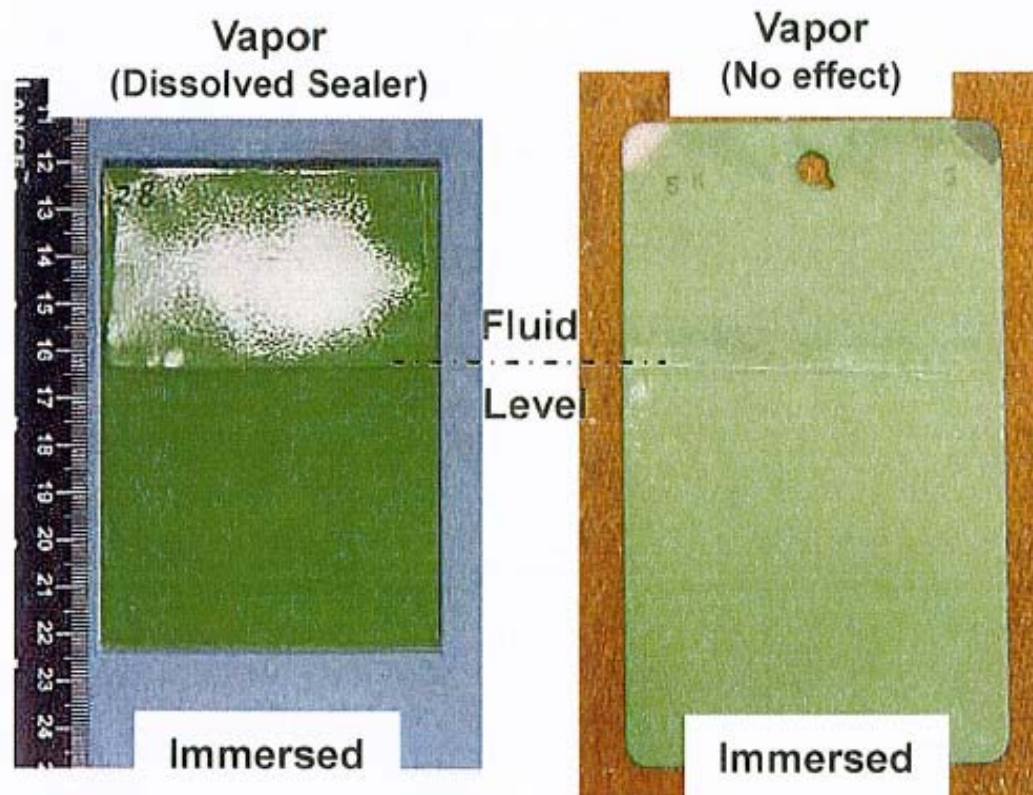


Inorganic Phosphate Sealer for Aluminum-Silicate Unaffected by Hot Fluids

☐ Stable in Hot Water

- After 24 hrs. at 120F (49C) in distilled water

Al-silicate
with 1st
generation
sealer in
PWEG test



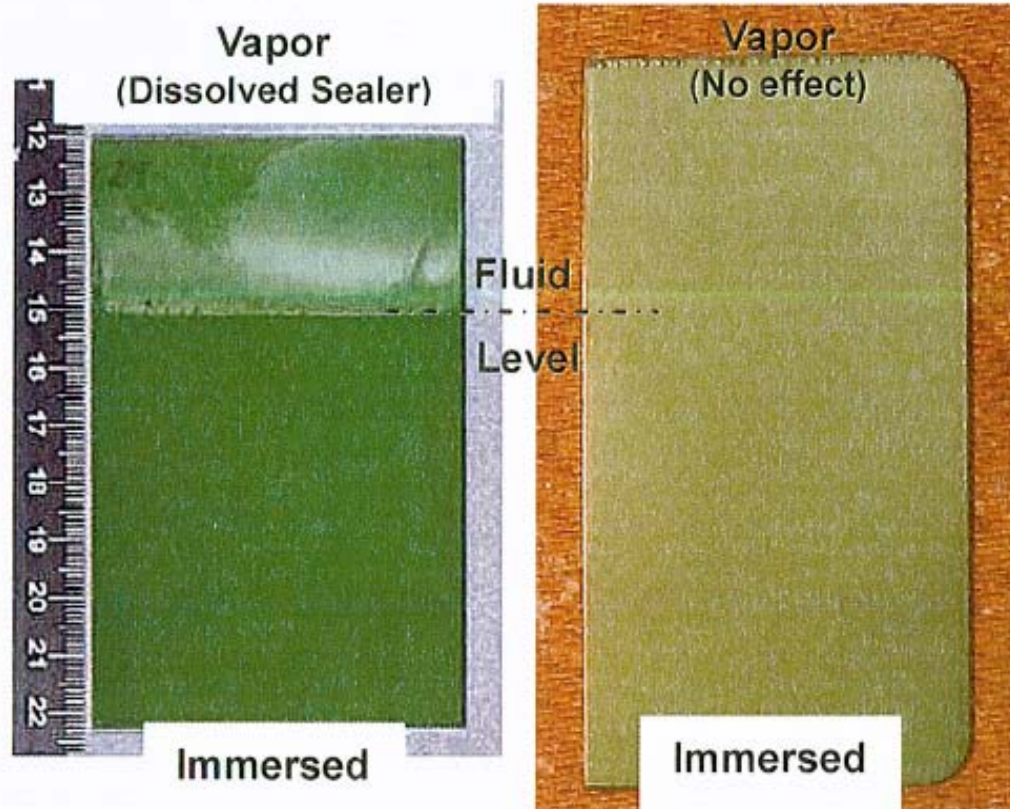
Same Al-
silicate
with new
sealer in
same test

Inorganic Phosphate Sealer for Aluminum-Silicate Unaffected by Hot Fluids

□ Stable in Hot Oil

- After 8 hrs. at 400F (204C) in MIL-L-7808 Oil

Al-silicate
with 1st
generation
sealer in
PWEG test



Same Al-
silicate
with new
sealer in
same test



Sealed Aluminum-Silicate Comparable to Sealed Aluminum-Chromate/Phosphate

❑ Salt Spray Corrosion (ASTM B117)

- 2000 hrs. scribed and unscribed.

no rust, pitting,
or undercutting
at scribe

(Coating on plain
carbon steel)



2000 hrs. B117



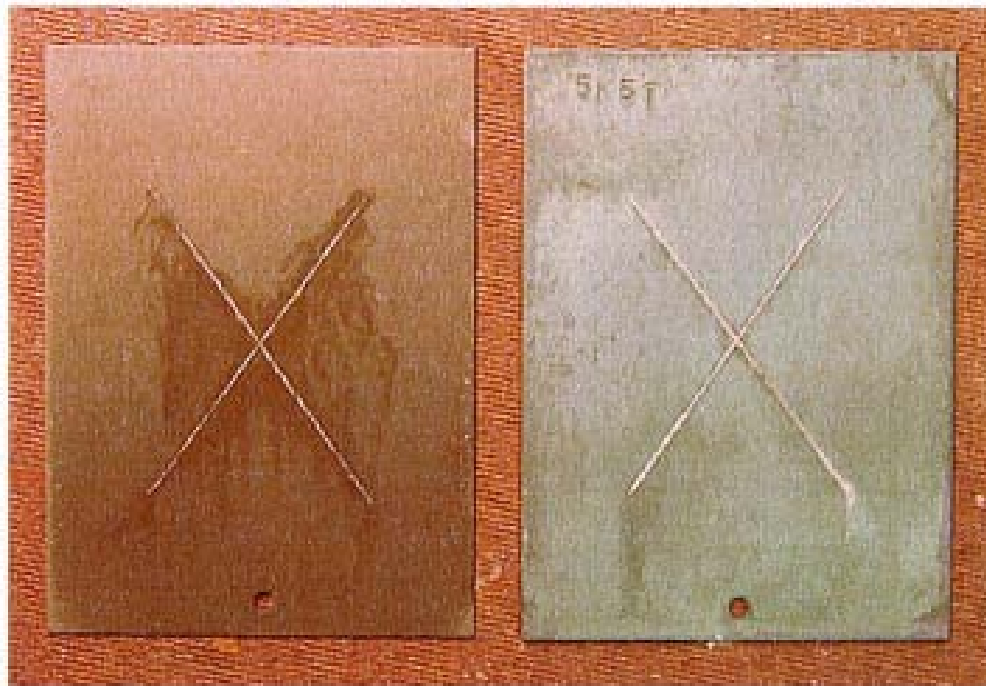
Sealed Aluminum-Silicate Comparable to Sealed Aluminum-Chromate/Phosphate

■ Heat Cycle Salt Spray Corrosion

- 10 cycles 6hrs. @ 750F (399C)/16hrs. 5% salt fog

Al-Cr/PO₄
sealed
with
Cr/PO₄

(4130 alloy
steel)



Sealed Al with Cr(VI)

Sealed Cr-free Al-silicate

Al-silicate
with
improved
sealer

(4130 alloy
steel)

PEWG Update

**With Inorganic Phosphate Sealer,
Al-Silicate Comparable to
Sealed Al-Chromate/Phosphate**

- ☐ Humidity Resistance
- ☐ Galvanic Corrosion Resistance
- ☐ Heat/Salt Resistance
- ☐ Adhesion/Substrate Compatibility
- ☐ Abrasion Resistance
- ☐ Hot Oil, Water Resistance - Sealer
- ☐ Corrosion Resistance - No Post Treat

Beyond PEWG - Aluminum-Silicate on HSLA Steel

□ Galvanic Corrosion Resistance

- Pyrowear 53 HSLA steel, with & without sealer

Sealed,
Cured
1 hour
at
425F



Sealed and
unsealed
(center),
Cured 4 hours
at 425F

1000 hrs., 5% neutral salt fog, B117

Aluminum-Silicate Handles Like Aluminum-Chromate/Phosphate

- ❑ **Single component (One Bottle)**
- ❑ **Easy to Apply**
 - Air-atomizing spray guns
 - No special spray booths
(humidity control a good idea)
 - Possible “drop-in”
- ❑ **Compatible with many substrates**
 - Carbon & HSLA steels
 - Stainless steels
 - Nickel-base alloys
 - Titanium
 - Aluminum
- ❑ **Water clean-up with no hazardous waste**



Aluminum-Silicate Is Processed Like Aluminum-Chromate/Phosphate

- ☐ Degrease substrate
- ☐ Blast with 120 mesh Al_2O_3 grit
- ☐ Apply Al-silicate
 - HVLP air-atomizing spray equipment
- ☐ Air dry 15 minutes
- ☐ Heat dry 15 minutes at 175°F
- ☐ Cure 30 minutes at 650°F
- ☐ Apply a second coat or post-treat as desired
 - Can defer cure of 1st coat until 2nd is applied.



Hazards of Inorganic Aluminum Metallic-Ceramics

Al-Cr₂O₇/PO₄

- Zero VOC's.
- 13.0 wt. % inorganic phosphates
- 3.3 wt. % Cr⁺⁶ (hexavalent chromium) before curing.

Al-silicate

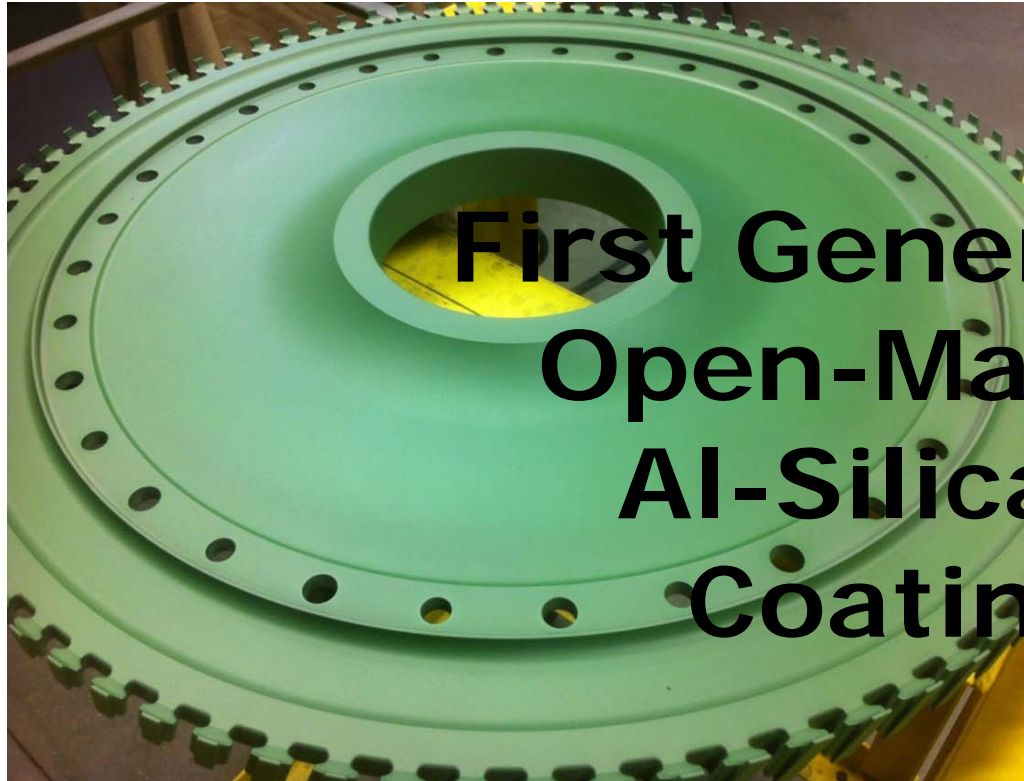
- Zero VOC's
- No hazardous mat'ls
- No carcinogens





Aseal[®] 5K Al-Silicate

Aseal[®] 5KT8 Sealer



**Aseal 5K^{†‡} + 5KT8 on PWA
GG-4 compressor disk**
Courtesy, Blastech Overhaul &
Repair, Bloomfield, CT

[‡] PWA 36595

**Polished Aseal 5K[†] on
V8 exhaust header**
Courtesy, Maryland Performance
Coatings, Sykesville, MD



[†] US Pat. App. 2006/0166014 A1

Aseal[®] 5K

Aluminum-Silicate

☐ Specified by Pratt & Whitney

- **PWA 36595 Rev. B**
 - **Issued July 2007, Revised Nov. 2010**
- **Used on PW4000 shafts**

☐ In Test at Other OEMs

- **GE Power**
- **Rolls-Royce North America**
- **GEAE**
- **SNECMA**

**Al-Silicate Coating System
Now Available That Can
Eliminate Hazards of
Carcinogenic Cr⁺⁶
in Al-Chromate/Phosphate
Compressor Coatings.**

Challenges

❑ Further Develop Capabilities

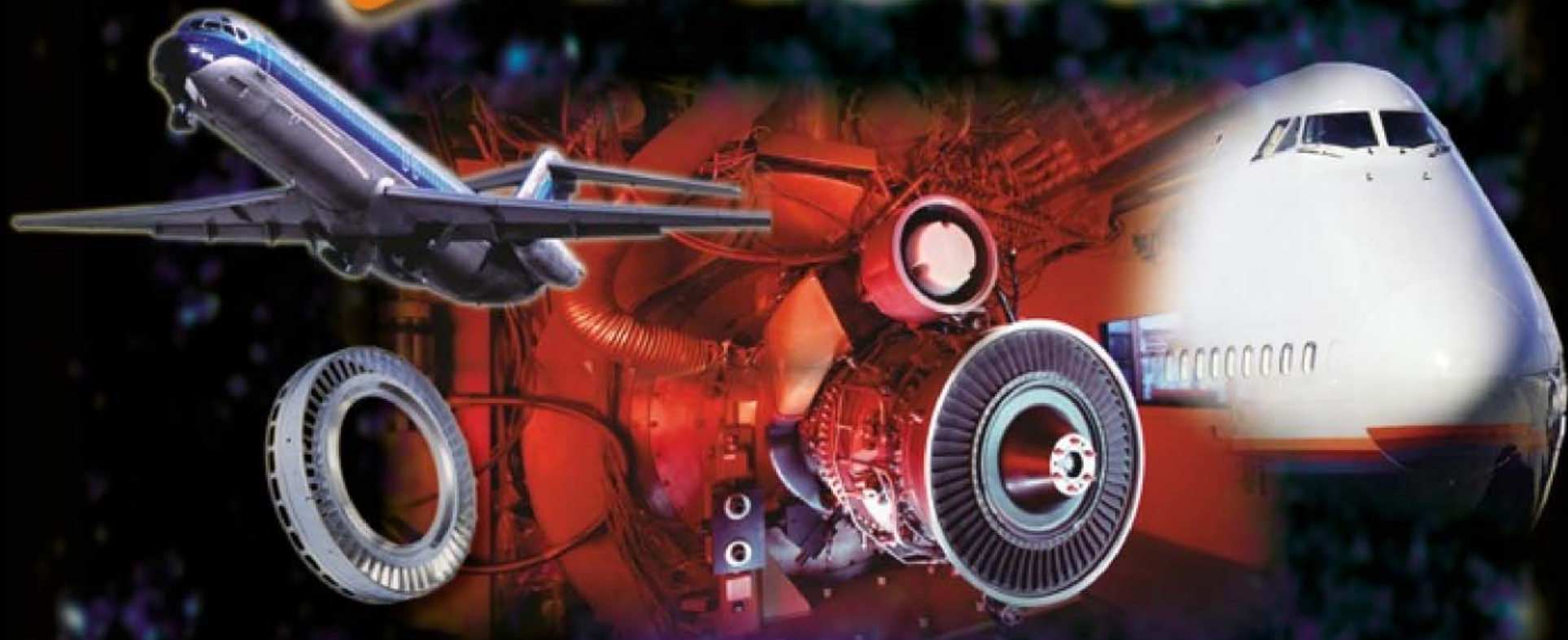
- Sealers?
- Low Temperature Cure?
- Smooth Finishes?
- Process Variables?
- Limits?

❑ Discover New Fundamentals

- 1 to 1 Correlation Not Guaranteed
- Ex. - Replacing Plating with Paint
 - Different thickness constraints
 - Blueprint Changes

❑ Produce Documentation

- Process Instructions
- Controls
- Prints & Drawings



Premium Coatings for the Aerospace Industry